CANADA / NEW BRUNSWICK
CONSERVATION AND
ALTERNATIVE ENERGY AGREEMENT

L'ENTENTE CANADA / NOUVEAU-BRUNSWICK
SUR LES ÉCONOMIES D'ÉNERGIE
ET LES ÉNERGIES DE REMPLACEMENT

CANADA/NEW BRUNSWICK
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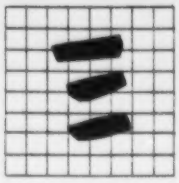
ALTERNATIVE ENERGY AGREEMENT



L'ENTENTE CANADA/NOUVEAU-BRUNSWICK
SUR LES ÉCONOMIES D'ÉNERGIE
ET LES ÉNERGIES DE REMPLACEMENT

WOOD-FIRED BOILER WORKSHOP

November 24-25, 1987
Newcastle, Chatham, N.B.

P R O C E E D I N G S

Sponsored by:
Energy, Mines and Resources Canada
Department of Natural Resources
and Energy, New Brunswick
P.O. Box 6000
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Nouveau-Brunswick

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WOOD-FIRED BOILER WORKSHOP

November 24 and 25, 1987

Newcastle, N.B.

Tuesday, November 24

Morning Session

Newcastle Town Hall

INTRODUCTION - E.T. Owens, Workshop Chairman

"Welcome to the second in a series of workshops devoted to improved efficiency in Wood-Fired Boilers. Many of you participated in the December, 1986 sessions and we are pleased to see you at this current edition. As well it is a pleasure to see representatives from Prince Edward Island and two participants from Newfoundland are scheduled to be here."

"The purpose of the Workshop is two-fold. It provides an opportunity to present solutions to individual or collective problems and it leads to greater economy in energy conversion based on wood."

"The format is similar to the 1986 undertaking with heating plant operating staff meeting this morning to be joined by consultants and manufacturers this afternoon. Tomorrow morning four sites will be visited each with specific appeal to those concerned with wood energy.

"Simultaneous translation of presentations and discussions is being provided and listening devices are available for those requiring same."

"This Workshop is under the aegis of Energy, Mines and Resources Canada and Department of Natural Resources and Energy New Brunswick and on their behalf I bid you welcome. It is also appropriate at this time to introduce the staff of DNRE who have organized the Workshop and will see that it accomplishes the purpose. They are: Peggy Jones, Sydelle Grobe, Marc Chenard, Jim Richard and Darwin Curtis; and they will be happy to assist you to gain the optimum from the Workshop."

"The opening session will be moderated by E.T. (Ted) Shuve, a wood energy consultant well-known to most of you. He has been involved in design, construction and trouble-shooting of wood-fired boilers in all Atlantic Provinces during the past two decades. His experience fits him admirably for leading this session."

E.A. Shuve

"Ladies and gentlemen this is a distinct honor and pleasure to be the Moderator for the opening session of this Workshop."

"We will follow the schedule set forth in the invitation to attend the Workshop."

"It will be mutually advantageous for participants and myself to develop a consensus of achievements in the past year as well as the problem areas requiring additional action. This consensus can be a major background for discussions this afternoon."

(A summary of the discussion on each topic follows.)

Boilers

The discussion centered on the I.D. fan, essentially related to control of underfire air or a build-up of fly ash on the fan. On balance cleaning of boiler tubes occupied two man-days twice annually.

Specific suggestions were a re-design of the I.D. fan to offset the fly ash accumulation; and re-positioning the damper motor to eliminate the effect of heat and consequent drying out of bearings.

Fuel

The Moisture Content varied from 36% to 60% over a range of fuel including pure hardwood sawdust to full-tree chips; but the predominant fuel was a mixture of sawdust, bark and shavings from sawmills. Full tree chips are the exclusive variety in P.E.I. although a miniscule quantity is used from sawmill sites.

Although an acceptable volume of oil displaced by wood residue was elusive, it was agreed that a green tonne of residue was equivalent in energy conservation to 40 gallons of oil (#2 and #6 combined).

The cost of fuel to the many different consumers is a reflection of the type of wood residue being used, the source of supply and services performed by the supplier. Under a matrix of conditions it is not surprising to find delivered fuel costing between $11.00 and $28.00 per green ton.

Storage - Conveying

The slope of bin doors and its relation to snow accumulation was noted as a factor for designers to consider more carefully in future installations. One installation has such a problem where the slope is 25° but a replacement is not planned for the present time. At this same site the reclaim system has experienced difficulty with solenoids which actuate the scrapers causing shutdowns bi-monthly on the average. Higher capacity solenoids are to be used in the current year.

One instance of bridging in the storage bin was reported during winter operation and it was cleared manually. In general frozen fuel was not considered a significant problem, principally because closer attention is given to storage control. However a gear box on the stoker needed replacement in one plant due to extended feeding of frozen blocks of fuel.

Access to the fuel infeed was stated as a problem which designers should address.

Combustion Chamber

A continuing problem for a number of installations is damaged refractory brick due to chipping off foreign material essentially fuel burned at incorrect temperature. In one instance molten ash was being deposited between the refractory and chamber wall resulting in damaged refractory. It was agreed that plastic refractory, because it was not laminated, was superior to standard refractory brick. Another instance of refractory breakdown was described as located near a chamber door which it was thought resulted from extremes of temperature - internal and external - when the door was opened too frequently.

It was suggested that despite the cost it was preferable to use stainless steel anchors for refractory brick.

A range of combustion chamber temperatures was reported by operating staff for their systems, with the majority in the 2800 degrees F level maximum. The variation is considered a function of the moisture content of the fuel and the percentage of bark it contains.

Ash

The quantity of ash in wood-fired systems is of the order of 1%-2% of the total fuel intake indicating a reasonably complete combustion. Its disposal does not present a major problem at present. Indeed in at least two instances it is being returned to the land as a fertilizer while for most plants land-fill is the destination of ash. As present plants evolve it is anticipated that the potential as a fertilizer specially for forest soils, will be demonstrated in the coming year.

Controls

A possible solution to the overheated damper control bearing, noted previously, was put forth by an operator who suggested a fan to deflect the heat from the bearing. The photo level scanners in some feed systems have caused problems because of voltage reduction. The preferred solutions included using shielded cable to a redesign incorporating internal "down volting" which would maintain the integrity of the system.

Computer access respecting trouble-shooting was mentioned by one operator and further discussions with a manufacturer to rectify the situation was indicated.

It was reassuring to learn that whether the plants were guarded or un-guarded no major problems were reported as to their operation or maintenance. Developments are proceeding to increased computer control of plant functions and emergency power packages are the next items to be introduced.

Luncheon

A buffet luncheon was served at noon in the Town Hall where the consultants and manufacturers joined operating staff.

Tuesday, November 24

Afternoon Session

Chairman- "We welcome manufacturers and consultants as additional participants in our afternoon program."

"The morning activity centred on specific reviews of the existing heating plants and referred to some which are at a conceptual or constructional stage. This afternoon's session will build upon the previous discussions and extend to the experience of consultants and manufacturers who will introduce discussions of the integral parts of combustion systems."

Fuel

Chairman-"the initial presentation will be made by Jim Piercy, P.Eng., who is Manager, Power and Process systems Division, ADI Ltd., Fredericton, N.B. Mr. Piercy is an Electrical Engineering graduate of University of New Brunswick and his career has included work in Alberta, Ontario, Quebec and the Maritimes."

(A copy of Mr. Piercy's remarks is included in Appendix 2).

Discussion-References were made to the variation in moisture content in different types of fuels and an indication of a trend to green or dry material. Since current supplies are almost exclusively from sawmill operations the conclusion was that green fuels would pre-dominate. However the future supply will be harvesting residues and these have been shown to be drier and more uniform in size and shape. The speaker added that woodlots and abandoned sawdust piles at mill sites were promising sources for immediate exploitation. A reasonable moisture content of the fuel consistent with the capital investment for a combustion system was stated to be the guide for an efficient installation and based on contemporary operations 45% + seemed to satisfy requirements. Screening and drying of fuels as well as its preparation were explored. The findings were that these functions should be at source as much as economically possible. Particularly was this principle felt to be important in chipping.

The potential of woodlots as a source of fuel supply was mentioned in the context of a continuing supply in all areas of the province.

Storage and Conveying

Chairman-"The imaginative development of a feed system for residue is the basis of the next presentation which will be made by Nazmir Bundalli. Mr. Bundalli is a Chemical Engineering graduate of University of London and is presently Program Leader, Materials Handling for B.C. Research".

(A copy of Mr. Bundalli's remark is included in Appendix 2)

Discussion - It was noted that the reclaim system is adaptable to all types of residues in addition to grains and similar agricultural commodities. The use of various sizes of augers was reviewed as solutions to jamming when larger than average particles are involved. Residence time in a storage bin is a possible constraint to free flow of material it was suggested but Mr. Bundalli responded that 48 hours appeared to be a maximum. The system is geared to F-I-F-O (first in, first out) and has performed remarkably well in tests to date.

The slope of bin walls is ideally 60-70° and installations at a British Columbia pulp mill and a P.E.I. fish farm are demonstrating the versatility of the system particularly wall configuration.

(A working model plus a 5-minute video provided a comprehensive explanation of the system).

Combustion Chamber/Boiler

Chairman-"Continuing the exploration of the wood-fired systems we turn now to the heart of the installation, which will be reviewed by E.A. (Ted) Shuve. Mr. Shuve has worked with many of this audience throughout Atlantic Canada. He has been involved in design, fabrication and installation of pioneer and state-of-the-art units for more than 20 years. He will share his experience with us through his presentation".

(A copy of Mr. Shuve's remarks is included in Appendix 2).

Discussion-As the speaker noted and participants' questions indicated the fire tube boiler is the most common type in wood fired situations. A rule-of-thumb in boiler design, he stated, is 6-7 sq.ft. of boiler area per boiler hp. With the best of equipment however, Mr. Shuve stressed that efficiency depended greatly on good housekeeping. His major reference in this latter consideration was to constant care of the components of the system particularly preventive maintenance, periodic cleaning of tubes, removal of fuel overflows and mopping up lubricating oil spills. He added that common sense dictates these actions which contribute to improved operation.

There was interesting dialogue on the need to suit the fuel to the combustor and the shortening of the cycle between the fire chamber and the heat exchanger. Although fuels of varying moisture content can be accommodated in most combustion chambers balancing of air and fuel and adjusting fuel flows may be delaying a design change.

Controls

Chairman-"Continuous operation at optimal efficiency is the objective of a combustion system and this can be accomplished by proper controls. Mike Bleakney, Solid Energy Systems, will describe the many aspects of this subject. A U.N.B. Civil Engineer, Mike has been associated with a number of recent ventures in the region and will illustrate why controls are essential".

(A copy of Mr. Bleakney's remarks is included in Appendix 2).

Discussion-The positioning of controls; their protection from excessive heat; access for replacement; and the materials of construction were items covered in the discussion. Although a limited number of problems was exposed the participants did agree on two subjects requiring additional attention, i.e. controls to improve downturn and air balance. These subjects were recommended for study within a context of research priority vis-a-vis costs.

WEDNESDAY, November 25

Morning Session

The participants visited four plants in the Newcastle-Chatham vicinity to learn first-hand of operational developments in wood-fired heating plants.

Brookdale Nurseries Ltd.

This flower nursery is heated by dutch ovens and fire tube boiler arrangements in two locations. The boilers were designed originally for oil heating and subsequently modified for roundwood and presently to wood residue. The owner, Lloyd Brown, does his own chipping on site. The entire system from fuel preparation to steam distribution is a personal design and is completed with in-house labor. Qualified in the mechanical and electrical trades, Mr. Brown is able to do much of the installation with a minimum of external professional and technical assistance. (A brief outline of this operation is in Appendix 3.

Miramichi Pulp and Paper Inc. Sawmill

The emphasis of this visit to the sawmill located at Nelson-Miramichi was on a fuel preparation unit, Shred Pax. Amongst the features of this unit is the automatic reversing of the mechanism when too large a piece of material impedes the shredding. The overall conveying system for disposing of residues was also viewed during this visit directed by the sawmill manager, David Gunn.

Hotel Dieu Hospital

A model institutional heating plant to supply energy to a 200-bed hospital is a succinct description of the system at the Chatham hospital. Edward Flannagan superintends the operation which was installed in 1985 and uses sawmill residue as a fuel. There have been no serious problems with the plant but modifications of original components and first-class maintenance result in efficient performance.

N.B. Power Generating Station

State-of-the-art power generation using a circulating fluidized bed is the primary reason to visit this experimental plant. Coal and oil shale are the fuels being tested presently and the plant manager, D. McDonald, stated that wood residue, separately and in combination with the other indigenous fuels, will be tested in 1988.

Workshop Closing

J. Richard, D.N.R.E., brought the Workshop to a close following the N.B. Power Station tour. He thanked particularly the hosts of the plant visits and the speakers at the technical sessions. He specially expressed appreciation of all participants to E.A. (Ted) Shuve for moderating the opening session.

APPENDIX 1

WOOD FIRED BOILER SEMINAR ATTENDEES

APPENDIX 1

"Wood Fired Boiler Seminar Attendees"

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APPENDIX 2

PAPERS PRESENTED

AT THE 1987 WOOD FIRED BOILER WORKSHOP
November 24-25, 1987
Newcastle, Chatham, N.B.

WOOD - A FUEL FOR THE FUTURE IN NEW BRUNSWICK

1. INTRODUCTION

Since the discovery of fire in prehistoric times, wood has been used as a fuel for heating, cooking and other purposes. It is probably the most widely available fuel product in most parts the world, and when it is harvested responsibly, is continuously renewable from generation to generation.

In New Brunswick, the early settlers found an abundance of wood with which to build and heat their homes. The forests provided a seemingly endless supply of firewood.

As time progressed, coal deposits were developed and coal became an important fuel, particularly for large institutional buildings and industrial applications such as railway and stationary power plants.

Coal oil and producer gas were synthetic fuels derived from coal that were convenient to use for lamps and other domestic purposes.

In this century, petroleum fuels gradually gained pre-eminince among other fuels, primarily because of the advent of the automobile and the subsequent worldwide development of oil resources.

The conversion to oil fuels for most small to medium sized institutional heating plants was largely complete by the mid-1950's. Older buildings, such as hospitals and schools had seen their boilers converted from coal or wood-firing to #2 or #6 oil combustion systems. Oil was cheap and plentiful, and was perhaps the most convenient of all fuels to store and handle. Combustion equipment too, was simple, cheap and reliable. It seemed that the use of wood as a fuel in the home and institutional setting had passed into history.

However, as is often the case, the situation changed considerably with the passage of a few more years. The price of oil was raised dramatically almost overnight, and shortages were experiences as the oil producing countries discovered the extent to which the industrial world depended upon oil for its basic existence. This realization of a dangerous dependence on foreign oil supplies came as a rude and expensive shock to many people who were responsible for the operation of industrial and institutional plants, as they watched oil costs spiral upward at alarming rates.

People turned their attention to other fuels and energy sources in an effort to escape the high costs and questionable availability of fuel oil. Coal was not seen as a popular alternative. It had fallen into disrepute because of the dirt and chemical emission associated with its handling and burning, and institutional heating plants were reluctant to return to the use of this fuel since the public were much less inclined to tolerate the nuisance associated with coal burning than they had been.

Attention naturally turned to the vast quantities of wood waste that was generated by the New Brunswick sawmilling industry, and which was largely regarded as a disposal problem by the sawmill operators. Teepee burners for incineration of wood residue were a common sight, and many thousands of tons were simply hauled to dumpsites for disposal. This material was abundant, and it had virtually no value. In fact it was a liability to many sawmill owners who had to pay to have it hauled away.

The large Pulp and Paper mills in the province were quick to develop new wood-burning boilers which reduced the vast quantities of oil they had required for mill operations. These mills were able to burn their own bark residues and purchase sawmill residues at very low prices. Since 1980, large industrial woodburning capacity in the province has more than doubled with new boiler installations in Atholville, Bathurst, Edmundston, Chatham, and Saint John.

Since 1977 many small industrial and institutional boiler units have been installed to use wood as a primary fuel. These include greenhouses, hospitals, a correctional institution, and a major University. The largest of these is the University of New Brunswick installation which displaces some 1.3 million gallons of #6 oil a year using approximately 35,000 tones of locally produced wood residue.

Wood burning in the Province has developed to the point where over 90% of the wood processing residue produced is now being put to use to replace oil as a source of energy, and for other purposes. Oil prices have declined from their peak values in 1984-85, and have remained stable during the intervening years, largely due to the collapse of the OPEC cartel's ability to manage the rate of oil production among its member states. The combined effect of cheaper oil and a reduction of the availability of low cost wood residue has been a slowdown in the development of new woodburning sites in the recent past. Increasing energy demand and an eventual decline on oil reserves will inevitably push oil prices higher over the next decade, and create a renewed interest in wood as a relatively inexpensive, renewable and locally produced fuel.

2. COMBUSTION CHARACTERISTICS OF WOOD RESIDUE

The primary active chemical elements in the combustion of wood are carbon, hydrogen and oxygen. Wood contains all three elements as well as many other chemicals in trace proportions. Wood residues also contain a number of other unwanted ingredients which can create problems in the combustion process. Combustion of wood primarily consists of two chemical reactions. Carbon reacts with oxygen to produce carbon dioxide, and hydrogen reacts with oxygen to produce water.

Unfortunately, green wood residue also contains a substantial proportion of free water due to the natural moisture in the living tree. A freshly cut tree might contain approximately 50 to 55% water by weight. Since lumber is sawn from green wood, the residue moisture content is typically in the 50% range, although it may decline to approximately 35% if the wood has been allowed to air dry for a few weeks before sawing.

It is well known among Boy Scouts that wet wood is difficult to burn. Fortunately, there is sufficient chemical energy in wood to evaporate a substantial quantity of water and still liberate useful heat provided the combustion system is designed to suit the wet fuel. Essential conditions for combustion are high temperature and the presence of a sufficient proportion of oxygen. Modern wood burning systems produce these conditions quite effectively, and will operate quite nicely on wood approaching 60% moisture content by weight. The useful heat available declines as moisture content rises due to the increased energy required to evaporate all the water before combustion can take place. Thus it is always desirable to reduce moisture content as much as is practical before burning is attempted.

The flue gas stream from the combustion of wet wood residue contains a substantial quantity of water in the form of steam. This produces the characteristic white plume from the stack of a wood-burning boiler during cold weather as the water vapour condenses upon leaving the stack. This water vapour consists of the free water that was evaporated before the wood was burned as well as the water vapour produced as a product of the combustion of hydrogen. Typical wood residue is approximately 6% hydrogen by bone dry weight, and this proportion of hydrogen will produce approximately 9 times as much water by weight, or 54% of the bone dry weight of wood. In practical terms, this means that 1 pound of fuel at 50% moisture content will produce approximately 77 pounds of water vapour in the stack gases. The useful heat liberated from the combustion will be reduced by the heat lost in vaporizing

this quantity of water (approximately 980 BTU per pound of water) as well as the heat used to superheat this steam to the temperature of the stack gasses. For practical purposes, one can assume that 1000 BTU of heat is required to evaporate one pound of water. If one assumed a theoretical "higher heating value" for wood fuel of 8700 BTU/pound for bone dry wood, it is easy to calculate the useful or "lower heating value" of wood fuel as 4350- 770 or 3580 BTU/pound as fired at 50% moisture content. This accounts for the evaporation of both the free water and the water produced by combustion of hydrogen.

One of the problems associated with wood-burning systems is the formation of "clinker" from the sand and gravel which typically contaminates wood waste containing bark. The bark becomes contaminated with dirt as it is skidded to a landing in the forest, and this dirt can adhere to the bark up to the point where it is burned in a boiler. Naturally, the sand and gravel will not burn, and at the 2000 degree fahrenheit temperatures that are typical in a wood furnace, it is softened sufficiently that it will agglomerate into a hard crust known as "clinker", fine sand particles can be stirred up from the combustion zone and in a semi molten condition will adhere to red hot refractory surfaces commonly used in small wood burning systems to maintain high combustion zone temperatures. This phenomenon can cause a clinker buildup on cell walls and gas paths that can eventually cause problems with combustion air fans due to altered flow characteristics.

If a refractory cell is allowed to operate a too high a temperature, the clinker will melt or "slag" and form a glass like coating which can plug air passages in grates and which is very difficult to remove. Normal clinker can be broken quite readily and aside from its extremely abrasive nature is not difficult to remove from the combustion chamber.

The sand particles which are swept up in the flue gases also cause abrasive damage to the tube banks since those fine particles which are allowed to cool and are not trapped by the refractory, effectively sandblast the metal surfaces they collide with on the way through the boiler. Generally speaking, the wetter the fuel, the more abrasion can be expected because more steam and excess air in the flue gases result in higher gas velocities in the system, and hence more carryover and impact damage.

3. MATERIAL HANDLING DIFFICULTIES

Wood fuel presents some problems in its storage and handling when compared to oil or coal. Fuel is generally in the form of small pieces ranging from dust particles up to perhaps 6" in length. The fibrous nature of the material means that it does not flow readily by gravity, and wood storage and handing systems must be designed so as to depend as little as possible on the effect of gravity. Chutes which slope at much less than 60 degrees above horizontal or which contain converging cross sections can be expected to give trouble. Because wood contains a high proportion of water, it tends to "pack" or solidify when compressed wood fuel at the bottom of a bin can be packed to an extremely hard mass which will show little tendency to flow at all. Likewise freezing temperatures can result in an increased cohesiveness in the fuel which can cause serious difficulties unless the wood storage and handling system is designed to minimize these effects.

Contamination of fuel with large pieces of wood, rock, or metal can cause plugging and equipment damage unless steps are taken to prevent such contamination, and to minimize its effects.

Pulp mills generally pass all purchased wood residues by a powerful magnet that separates ferrous metals and then through a screening and hogging process that eliminates oversized pieces of wood. Smaller installations rarely provide on-site processing, but arrangements are made with the fuel supplier to screen and or hog the material before it arrives at the boiler plant.

Even with these precautions, conveyor plugging will occasionally occur in the best of systems, and the equipment must be robust enough to withstand the resultant overloading and must be provided with cleanouts and access ports at all critical points in the sytem.

Control systems should detect and annunciate jams before a serious problem develops.

4. ENVIRONMENTAL CONCERNS ABOUT WOOD COMBUSTION

Much has been written during the past few years about air pollution as a result of the combustion of wood in the airtight stoves that have become popular over the last decade. It is true that wood that is burned in an oxygen deficient environment will produce numerous hydrocarbon compounds and other products which are toxic. One of the most easily recognized of these is carbon monoxide gas, but there are a number of tarlike substances such as creosote which are recognized as both toxic and a potential fire hazard.

Without exception, these harmful byproducts of wood combustion result from poor combustion conditions of either too little air, too low a temperature or both of these. Larger modern woodburning systems do a very good job of achieving complete combustion with little unburned residue either in the flue gas or on the grate. Careful system control will eliminate the black smoke that can result from poor fuel, fuel feeding systems or inadequate air control and produce a relatively clear stack.

Particulate carryover can be a serious nuisance associated with a wood burning boiler, although this problem is eliminated in modern systems through the use of dust collection systems which mechanically remove particles of unburned carbon from the flue gas stream before it is sent to the stack. The multicyclone is the most common type of dust collector on small to mid sized units, and these devices do an effective job in meeting the standards of 500 milligrams per standard cubic meter of flue gas which is the current N.B. standard for particulate emission.

The carbon dioxide gas which forms a large constituent of the flue gas in a wood burning system is not a toxic gas, but has been identified as the cause of the "greenhouse effect" which is claimed to be causing a gradual change in the earth's climate. All carbon based fuels produce CO^2 production is the fact that the wood residues that are burned would have otherwise decomposed in nature over a longer period of time, and would have eventually produced the same quantity of CO^2 gas as the biomass oxidized on the forest floor or in a dumpsite. Coal or oil is stable over many thousands of years, however, and if left unburned will not contribute to CO^2 production.

Wood combustion produces no sulphurous compounds that contribute to the acid rain problem. In fact, wood ash has a slightly alkaline quality that tends to neutralize stack acidity at sites where both fuels are burned together.

Stack emissions from wood-burning systems are the least harmful to the environment of any common fuel when all the foregoing points are considered.

The other environmental aspect of solid fuel combustion is the solid incombustible residue or ash that remains as a waste product. Wood "ash" typically contains sand and gravel, some charcoal or unburned carbon, as well as the true "ash" constituent which is a fine gray powder made up of trace chemicals from the wood. Wood typically contains from 1 to 1.5 percent ash by weight, and considerably less by volume since wood ash is quite dense in comparison with wood fuel. Wood ash is used as a fertilizer in some circumstances since it

contains many trace nutrients from the wood tissues. Coal on the other hand typically contains 10 - 20% ash and it can be an environmental problem because of the sulphur compounds and low level radioactive elements that are often present in coal ash.

Oil combustion produces very little ash, but it is composed largely of sulphurous compounds which are highly acidic.

Combustion of wood fuel produce more ash than burning oil, but considerably less than firing coal, and the ash produced is environmentally much more benign than that of either of these competitive fuels.

From this brief discussion it is evident that wood residue is a very good fuel from an environmental standpoint.

5. SOURCES AND AVAILABILITY OF WOOD FUEL IN N.B.

Most of the wood fuel consumed today in the province is residue from pulpmill or sawmilling operations. There are approximately 1,103,000 bone dry tons of this material produced each year in the province, and approximately 900,000 bone dry tons or 81% of it is presently used as fuel within the province. There is still a potential to build a few small wood burning plants at various locations in the province to take advantage of some of the residue that is presently available, but any major new projects may have to look at sources other than mill residues for fuel supplies.

It is self evident that sawmill waste would have been the first fuel source to be utilized as the market for wood fuel developed. After all, the product has been removed from the forest, processed into the necessary small particles and stored in piles or bins at a central location where it can be easily loaded on a highway truck for delivery to its destination. Moreover no cost had been assessed on the procurement and processing of the residue since it was seen only as a necessary byproduct of the production of lumber and not a product with a value of its own.

As the easily accessible wood residue from sawmill yards is gradually used up, attention is turning to the vast quantities of wood residue that is left in the forest as part of the normal wood harvesting operation. This residue consists of tops, branches, leaves, and even the stumps of trees that are now cut just for the stem portion. Already, there a few operators in the maritimes who are operating chipping equipment to salvage some of this "waste" material and turn it into wood fuel for use in pulp mill boilers.

These salvage operations are very much the exception, however, and vast quantities of potential wood fuel is presently left to rot in the forest, or is wastefully incinerated in the forest in preparation for replanting.

A great deal of research and testing has been done into methods and equipment to economically harvest, process and ship forest residue fuel. Newer methods of harvesting where the whole tree is brought to roadside before delimbing and topping tend to concentrate the residue at accessible locations that may encourage the processing of this residue into fuel chips.

The cost of this type of fuel is somewhat higher than current market prices for sawmill residue. A nominal cost of approximately $9.00 per ton loaded in a van at the harvest site is considered reasonable at present, although improved equipment and methods may reduce this cost in the future. The value of any wood fuel, however, is closely linked to the price of competing fuels, which in New Brunswick, is the price of oil. In todays energy market, oil is relatively inexpensive, and its price is quite stable. Recent experience has shown that the price and availability of oil can change very suddenly, and the more predictable cost of wood residue may look much more attractive than at present.

The salvage of forest residues has several socio-economic benefits to the community at large that are worthy of recognition by government. These include:

Increased employment of woodsworkers and truckers, with corresponding reductions in unemployment and welfare benefits and increased tax revenues.

Improved balance of international trade due to diversion of payments from foreigh oil suppliers to local fuel suppliers.

Assistance in the reforestation process by removing slash and debris from logging sites.

Reduction of harmful stack emissions due to oil or coal firing.

Forest residues represent a vast potential fuel resource. Present harvesting operations in New Brunswick produce an estimated 6 million wet tons of this material per year. This is approximately equivalent to 216 million gallons of #6 fuel oil in terms of useful heating value. This represents nearly three times the present wood fuel consumption in the province. It is clear that there is sufficient fuel available from harvest residues alone to support a greatly expanded wood energy program in New Brunswick, and all of this is possible without cutting any additional trees in a province that is cutting wood at near the maximum sustainable rate.

Other sources of wood fuel such as whole tree chipping are not likely to be developed in New Brunswick, since it is likely that most of the presently unmarketable species of hardwood will soon be developed for higher value commercial purposes.

6. SUMMARY AND CONCLUSIONS

Wood has historically been important as a source of energy in New Brunswick, and its use as a fuel has more than doubled since 1980.

Wood can be difficult material to handle, but it is seen to be a good fuel with very little environmental impact compared to most other fuels in common use in the Province. Modern wood-burning equipment can provide reliable performance without production of harmful stack pollutants or toxic ash products.

Until now, most woodburning installations have used wood processing residues as fuel. Approximately 90% of this material is now committed for use as fuel or other purposes, and expansion of wood burning capacity to a great extent will require the development of new fuel sources.

The most likely source of large quantities of wood fuel in the future will be the salvage of harvest residues that are presently left as waste in the forest. Harvest residues are a vast nearly untapped energy resource that can be processed into wood fuel using existing techniques at reasonable cost.

As oil prices climb, the wood fuel resource in the Province will undoubtedly be developed to its economic potential to replace expensive oil from foreign suppliers with a renewable locally produced fuel while ensuring the maximum economic and silvicultural benefit to the Forest Product Industries.

THE COMBUSTION CELL AND BOILER

E.A. SHUVE

ATLANTIC HEATING PLANT SPECIALTIES INC.

I have been asked to speak to you today about the combustion chamber and boiler. The combustion chamber is sometimes referred to as the dutch oven or the combustion cell, the boiler is often referred to as the heat exchanger. This is because it performs the function of transferring the heat from the hot gases to the heating medium to provide the hot water or steam required in the heating or process application.

I deemed it necessary to clarify these terms as I know I will refer to them during the course of my talk, and I would like to make it clear that I am not talking about different types of equipment when I refer to the various names I have just defined.

I, would first like to commend the organizers of this conference for the format they have selected, and that they have had the wisdom to ask each speaker to address a specific area of a wood burning plant. This has allowed each of the speakers to concentrate on a specific area of the system and I am sure this will give you a more detailed description of a total plant. This format also has the advantage of giving you a much broader look at a total plant as compared to having one person detail a total plant and give you only the benefit of his or her ideas.

Seldom does one find themselves in a position where they are speaking to people who have a wealth of practical experience in dealing with the subject to be presented. However, this is the situation as most of you are presently operating wood fired plants. I hope with my experience which I have gained over the past 30 or 35 years I can add to your knowledge of the combustion cell and boiler as they are used in a wood burning system or plant.

The combustion cell and boiler are the heart of a wood burning plant. However, they are only as effective as the other components such as fuel feed and controls. Some of you who have been around as long as I have will remember when it was discovered that instead of burning wood in a single steel drum that you could gain more heat by placing two steel drums one on top of the other in a horizontal position with a pipe connecting the two drums more heat could be derived from the second or top drum. This my friends was the beginning of the combustion cell and heat exchanger, and at that time it was found to be quite effective in that it delayed the escape of the hot gases into the smoke stack and extracted the heat to be put to good use providing space heat for the area in which the unit was contained.

We like to think that we have come a long way since that time, and we have, in that we have refined the system and made it more efficient. However we still employ the same principle of putting the heat exchanger on top of the combustion cell, or beside it or on the end of it in order to obtain the benefit of the heat transfer of the heat contained in the hot gases which are emitted from the combustion cell.

So much for history, I would first like to deal with the boiler or heat exchanger. In most of the wood burning applications we use a fire tube boiler, and the boiler which appears to be best suited to wood firing is the fire box type of unit. Due mainly to the fact that this type of boiler provides a larger combustion space and allows the necessary time and number of passes to transfer the heat from the hot gases to the heating medium which provides the energy in either steam or hot water form. The fire tube boiler is practical for applications requiring less than 2500 or 3000 square feet of heating surface and pressures of 250 p.s.i. or less. For applications above these sizes and pressures it becomes more practical to consider the water tube type of boiler. Either the A or D configuration of boiler lends itself to a good wood firing system.

Sizing the boiler can sometimes be a very confusing excercise. In sizing we will refer to a size in kw or horsepower or in b.t.u. However, when we go to the boiler manufacturer he asks how many square feet of heating surface we require. The number of square feet of heating required to produce a boiler horsepower of kw or million b.t.u. is dependent on the efficiency of the unit.

The Department of Labour will still use a figure of 10 square feet per boiler horsepower. Some of the packaged type oil burning units use a figure as low as 2.5 square feet per horsepower. However I have found that for most wood burning plants of today's design a figure of 6-7 square feet per boiler horsepower is quite adequate.

The main points in selecting a boiler or heat exchanger are that the unit is of adequate size, that is it has sufficient heating surface to do the required job and it has been approved to operate at the pressure you require. The boiler also must be registered in the province in which it is being installed.

The boiler must be fitted with the proper trim to meet the applicable codes, and to perform the functions required for safe operation of the boiler. The boiler must be fitted with approved safety valves, low water cut-outs, pressure guage and pressuretrols or aquastats, dependent on the service required. The boiler must have proper insulation and jacketing, and access platforms must be provided to allow the operator to service the various valves, etc. on the boiler.

The access platforms are much more important in a wood firing operation on the boiler is usually located in an elevated position to allow for proper installation of the combustion cell.

The care and maintenance of the boiler is most important as this has a direct and very significant effect on the efficiency and output of the system. This becomes more important when using wood chip or biomass fuel of any type, due mainly to the variations in quality of fuel. A poor quality of fuel such as one containing a high percentage of bark tends to produce a higher content of ash and clinker which will effect your operation both in the combustion area and in the boiler heating surfaces. The clinkering will close off the air feed from coming up through the grates which creates an imbalance of air and results in poor combustion. This poor combustion means that the fixed carbons which are not burned are carried along the gas path and lodge in the tubes and other heating surfaces which drastically effects the heat transfer. Tests have proven that 1/8" of soot or fly ash on the tube surface will reduce efficiency by as much as 25%. I cannot give you a hard and fast rule as to when or how often you should clean your boiler, I can only say that you should clean it as required, if you feel that your boiler is sooting up too quickly you should look at your fuel quality as well as the total operation of the system. One thing I would like to stress that in all my travels around boiler rooms I have found that a clean boiler room is a well operated boiler plant and has far less problems than a plant that is not kept clean and well oiled. I suggest that you should be able to maintain a wood fired boiler room or plant in as clean a condition as your own living room, and I can assure that if you take that attitude toward your plant you will have less problems with your mechanical equipment.

The combustion cell or dutch oven is where the actual burning of the fuel takes place. The combustion cell is usually constructed of fabricated steel and is of double walled construction. The inner walls are lined with refractory normally to a thickness of 6-9" with a heat rating of 2800°F. The outer casing of the chamber is covered with a suitable type of glass block insulation and is normally clad with a pre-painted corrugated steel sheeting. The combustion cell must be provided with sufficient fire doors and ash doors to allow for the complete removal and cleaning of both the fire bed and ash pit areas. Most cells are constructed with an air chamber where the combustion air is preheated to increase the efficient operation of the unit. The air chamber also provides an area for the heat from the refractory to dissipate and keeps the refractory cooler and hopefully extends the life of this part of the unit.

Most burning is done on a cast iron grate surface with fuel fed from either below or above the grate surface. The underfed type of system appears to be the most common and is used when possible. In this type of system the fuel is fed through an auger and forced up through a retort onto the grate surface.

When you examine a wood burning plant you will find that in the pile of burning fuel that all the burning takes place in the top two inches of the pile, although the pile may be two or three feet deep. By feeding the fuel from the bottom you provide a drying period for the fuel while it is gradually pushed to the top of the pile by new fuel whch is being fed up through the retort. The result is that when a particular portion reaches the top of the pile it is at the ignition point, this helps to provide a smooth operation and constant flow of hot gases to the heat exchanger.

The combustion cells are fitted with both under-fire and over-fire air fans to provide the proper amounts of air required for combustion of the wood fuel. These fans should be fitted with dampers to allow for the necessary adjustments required both to balance the air ratios and to accommodate the type of fuel being used, relative to quality and moisture content. The system is also fitted with an induced draft fan, this allows us to operate our cell in a negative pressure state normally at about four to six inches of water column.

Combustion cells in most installations are fitted with temperature indicating devices, and the temperature within the cells can be reasonably controlled. The Department of Labour now insists that in most installations a means be provided to extinguish the fire in case of a low water or loss of water feed to the boiler. Most combustion cells are now equipped with such devices and provide the safety required for the heat exchanger to prevent overheating.

This is only one type of combustion cell and feed mechanism. I can assure you that there are many others in use which employ other principles and work equally as well as the unit I have just described. I have seen some units that in my opinion and in the opinion of many of us is this room should not work, however they do work and work very well, I have seen this.

In closing I would like to stress that in my experience the more simple and uncomplicated we can keep things in these systems, the better they work and the less problems and breakdowns we have. One definition I have heard of modern technology is that we take something very simple and make it complicated. We must be very careful not to let this happen in this industry, we have good designers and good manufacturers in this province and we should use them, remember we have been using wood fuel in one form or another for a long time so we do have a lot of experience.

I trust you have gained something from this and I thank you for your attention.

STORAGE AND FEEDING OF BIOMASS

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Flow of biomass, and particularly, the lack of flow is a special concern as biomass is notorious for hang-ups and plug-ups. A major problem with biomass is achieving reliable flow from storage systems. Stoppages of flow are common, leading to disruptions in the energy conversion system. When such stoppages occur, it is necessary to resort to primitive solutions such as thumping the bin walls or prodding into the material as illustrated in Figure 1. Even dynamite has been required on occasions!

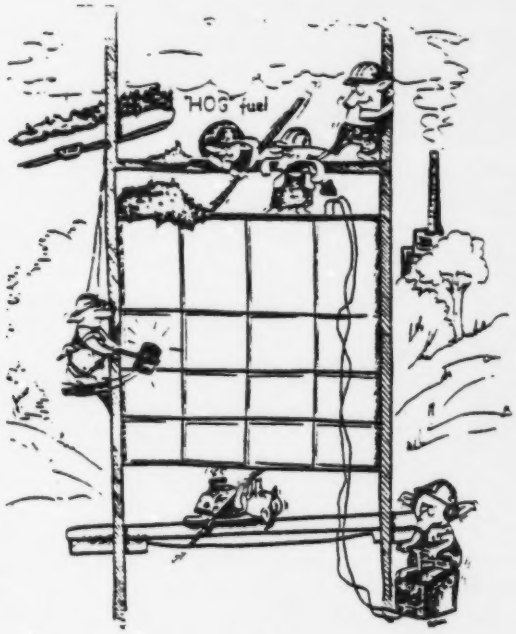

Figure 1: Typical Biomass Storage and Feed Problems!

Our research project started back in 1980 at a fairly fundamental level. It was obvious at this stage that there were no proper design criteria to allow for the fact that biomass can be a very variable material, ranging in its flow characteristics, from being a relatively free flowing material to a very difficult material in terms of its flow characteristics.

Lack of proper design criteria leads to a lot of myths - the single biggest myth being that storage bins and hoppers must have negative slopped walls (see figure 2) to avoid material hang-ups.

These sorts of myths lead to monstrosities - big outlets with very large feeders which are expensive to install, operate and maintain. The whole approach to biomass storage and feeding has been to use heavy duty systems with a lot of brute force.

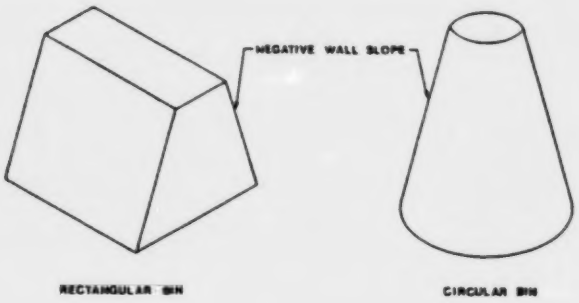

Figure 2: Bin Geometry Currently Used

The first phase of our research project involved some fundamental evaluations of the flow characteristics - essentially determining the strength of the material. Figure 3 represents the typical flow characteristic of biomass. The main conclusions from those evaluations were:

- biomass has an enormous resistance to funnelling (or flowing over it self). Bin-feeder design that relies on material funnelling or flowing over itself will result in problems.

- biomass, on the otherhand, is relatively weak if failure of material takes place along the walls of the hopper - i.e., a mass flow system can work very effectively.

A converging hopper is desirable - the design of the hopper is obviously quite critical. The mass flow hopper walls must be sufficiently steep and smooth to allow flow to take place preferentially over the walls of the hopper instead of material funnelling or flowing over itself. The friction of the inside of the walls of the bin is important. Use of a low friction liner is often required in order to permit the use of practical hopper slopes.

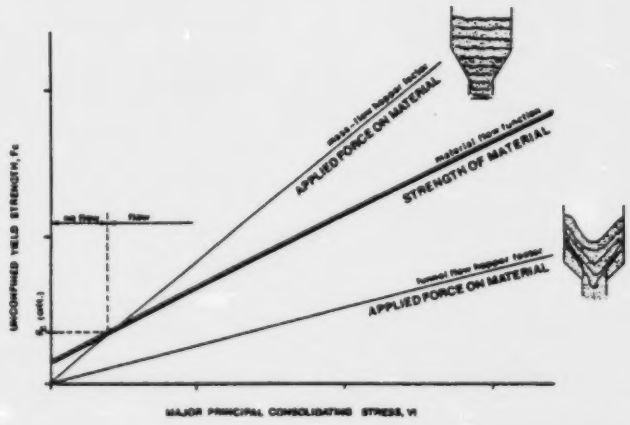

Figure 3: Typical Flow Characteristics of Biomass

The bin outlets predicted from laboratory evaluations were surprisingly, quite small and hence, very practical. A major advantage of using a converging hopper with a small outlet, is that the cost of the discharge feeder can be kept low without limiting the storage capacity of the bin.

PILOT SCALE TESTS

The results of the laboratory tests appeared to be too good to be true and had to be confirmed. A 80 m3 experimental bin (figure 4) was constructed to permit confirmation of the results at a fairly realistic level. The bin had an adjustable wall to permit variations of the width of the outlet and hopper slopes. The length of the bin was fixed at 4.6 m.

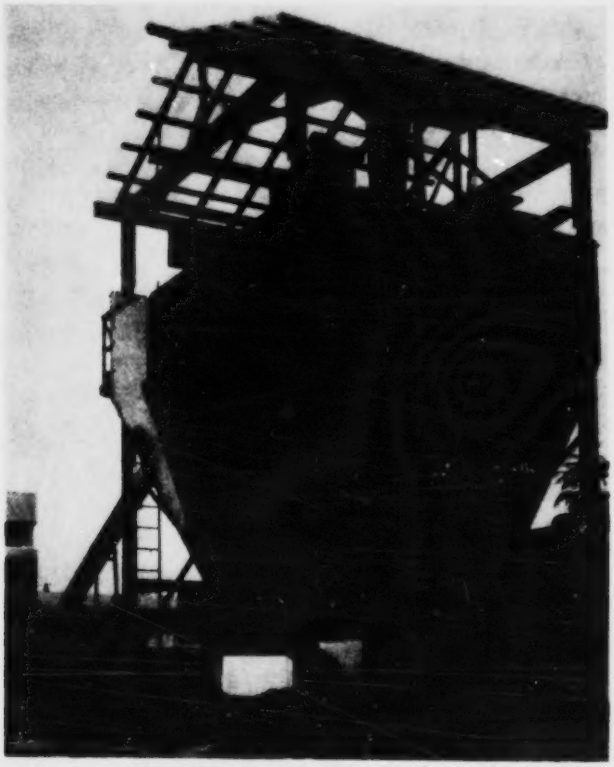

Figure 4: Biomass Experimental Bin

The first series of tests on the experimental bin were done without the discharge feeder (figure 5) to confirm the hopper geometry independently of the feeder. These tests confirmed that with the correct bin geometry, biomass can flow quite freely with converging hopper walls. However, with incorrect hopper slope or outlet width, the material is capable of bridging quite severely. Correct bin geometry is hence, essential.

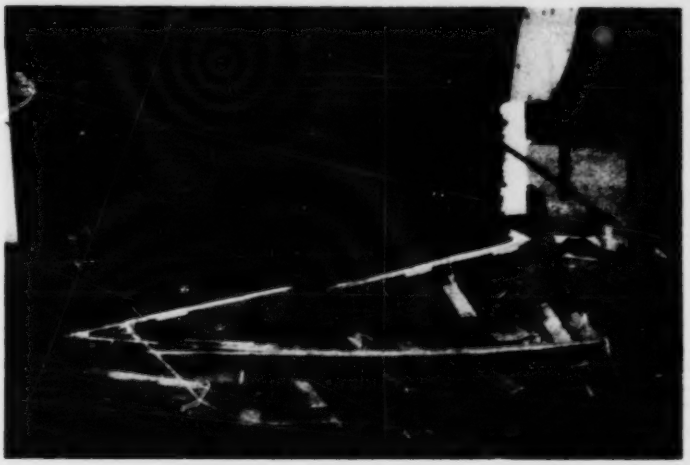

Figure 5a: Biomass Flow Freely

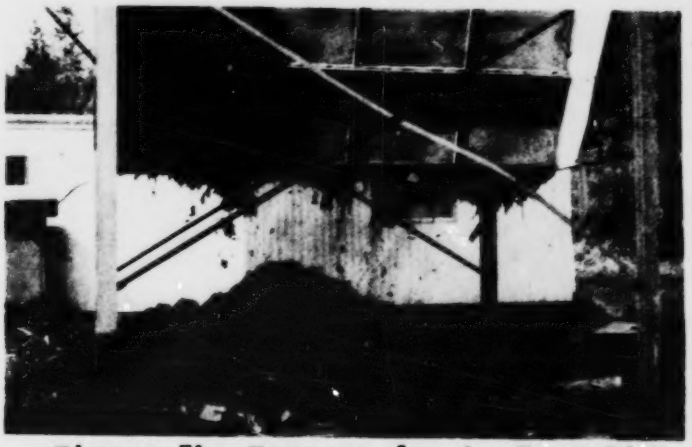

Figure 5b: Hang-up due to Poor Bin Geometry

The next phase of the project involved the discharge feeder. We started out with a multiple screw feeder. Figure 6 illustrates typical problems with most conventional discharge feeders:

- flow taking place primarily from the rear of the bin

- material in the front of the bin remains stagnant. If the bin is continuously refilled to maintain a certain level of material in storage, the stagnant material gains strength over a period of time, especially during the winter months when it can freeze up.

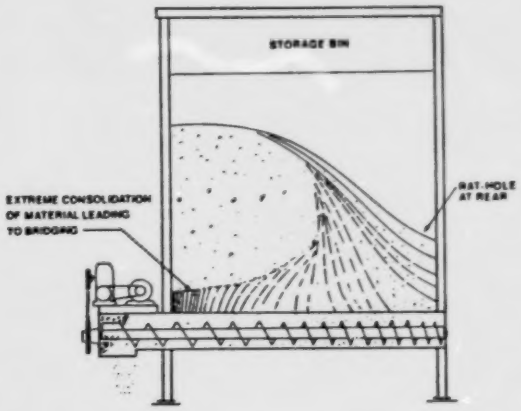

Figure 6: Typical Discharge Feeder Problems

- High power requirements by the discharge feeder, often resulting in the stalling of the feeder. A large portion of the feeder power is used to compact or consolidate material in the bin, leading to severe plugging or bridging of material.

Having defined the feeding problems as above, the solutions surprisingly were quite simple. It was necessary to reduce compaction of material by the feeder and to achieve more uniform flow. It was especially important to avoid stagnant pockets at the front of the bin.

Performance of the screw feeder was improved with relatively simple modifications. The feeder was suspended on four "come-alongs" (Figure 7) and dropped a little at the front to open up a gap between the top of the screws and the bin outlet at the front. This modification promoted flow of material at the front where compaction of material was earlier taking place. Substantial improvement was achieved with this modification.

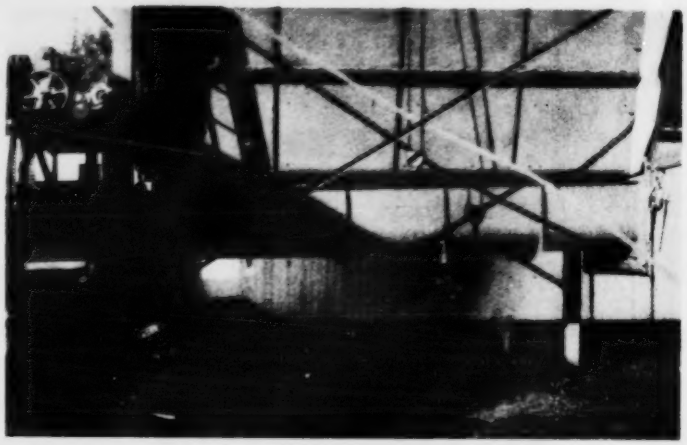

Figure 7: Modified Feeder Layout.

Further improvements were made to the outlet of the bin profile, until uniform flow was achieved through the full length of the bin.

Measurements of the power requirements (Figure 8) of the screw feeder showed that as the performance of the feeder was improved, power requirements dropped until optimum performance was reached. At this point, power requirements were minimal. It was concluded that the ideal feeder was one that required the least amount of power and, hence, could do least damage to material.

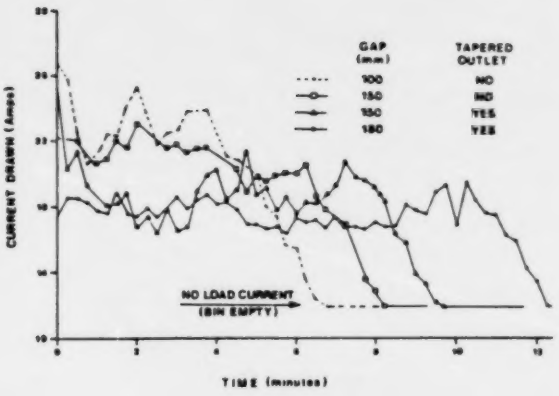

Figure 8: Measurements of Feeder Power Requirements

This reasoning led us to a simple belt feeder which we designed, constructed and operated with a 1.1 kw drive. This is in sharp contrast to the 22 kw drive required to operate the earlier multiple screw feeder.

Experience with the screw and belt feeders showed that the conventional feeder systems can be made to work better with relatively simple modifications which reduce compaction of material by the feeder and allow more uniform flow of material throughout the bin. These feeders are however, limited by length and capacity as some compaction and non-uniformity of flow was inevitable.

A feeder system without the above limitations was required. This led us to the new Non-Consolidating feeder (Patents Pending) (Figure 9) which results in no compaction at all by the feeder as there is no friction or relative motion between the feeder deck and the stored material.

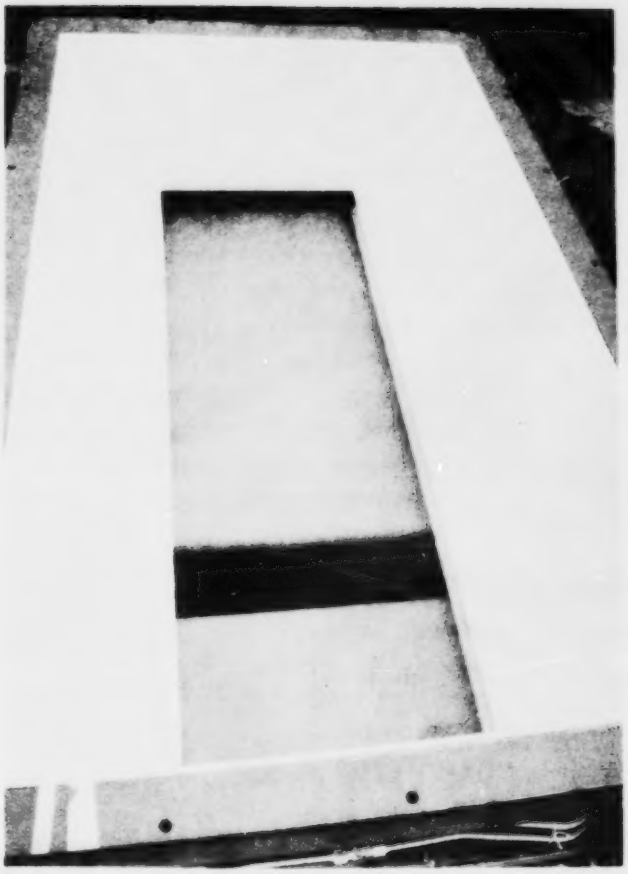

Figure 9: Non Consolidating Feeder

First-in first-out flow takes place, irrespective of the length of the system, and contents of storage are periodically renewed. Problems of bridging (or hang-ups), freezing and material degradation are avoided. The new feeder is very versatile and can be adapted for numerous applications and bin configurations.

Further developments are currently underway to allow the feeder to separate large frozen lumps of biomass. This is currently a serious problem with outside storage and reclaiming of material. During the winter months, presence of large, frozen lumps lead to serious operating problems.

Cost comparisons with several conventional bin-feeder systems show that the new system is very attractive in terms of capital, operating and maintenance costs.

ACKNOWLEDGEMENT

Funding for the projects were provided by the Canadian Government under the ENFOR and Bioenergy Development Programs.

AN OVERVIEW OF CONTROL SYSTEMS FOR WOOD FIRED BOILERS

presented at

Combustion System Workshop
Newcastle, N.B.

November 24, 1987

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Solid Energy Systems Ltd.

INTRODUCTION

The purpose of a control system is to ensure that a variable quantity or set of quantities is made to conform to a prescribed norm. In the case of heating plants, to maintain boiler steam pressure or outlet water temperature between prescribed set points, or points which may be altered at the direction of equipment external to the actual heating plant. Briefly, this is the primary purpose of whatever control system is used in a wood fired boiler room - Supply more heat/supply less heat to the boiler.

Of course, there are conditions which must be met to satisfy the "More heat/less heat" command. Fuel, heat and air must be available in proper amounts and proportions when required, and in turn this requires a chain of supporting conditions leading back to the fuel storage and ahead to the flue. In addition, we require that all equipment in the system operate in a way that prevents property damage or personal injury. Many of these conditions can and are met through proper equipment design, but those that are not or cannot be satisfied through this method must be met by other means.

I recently visited a wood fired boiler plant that had been supplying heat to a Maritime manufacturer for a century or more. Prior to the 1950's it had also been generating

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electricity by means of a steam engine driven generator to meet the needs of the plant and some of the surrounding village. Prior to the use of electric motors, motive power requirements for the plant had been supplied from a steam engine via belts, pulleys and shafts. Although at first glance it appeared the boiler room had changed little since the days of James Watt, the present boiler had been installed in the 1950's. A smaller boiler (approximately 800 sq. ft. of heating surface) had been installed when the requirement for in-plant power generation had disappeared. The arrangement was an HRT boiler over a gravity fed dutch oven. The plant distribution consisted of a single pipe steam supply and gravity condensate return.

However primitive the plant might have seemed, the control system had many features which would be difficult for the best designer to achieve. Most remarkable was the ability to sense, form decisions concerning and act upon several analogue inputs almost simultaneously. If boiler water level fell, as indicated by the water gauge, a make up water pump would start. If boiler pressure fell, a gate in the fuel chute would open or the fire doors would be opened and plant scrap material added to the fire, depending on the availability of fuel from each conveying system. Depending on the flame condition and flue emissions, combustion air dampers would open or close. Every night after the five

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o'clock whistle blew, the fire would be allowed to burn out, and every morning two hours before the eight o'clock whistle, a new fire would be started and steam pressure built. Best of all the control system required no electrical power to operate. It was flexible, adaptable, tolerant of design errors, could make corrections to programming errors, could learn from experience and produce (with his wife's help) its own spares. However, this human control system was not as fast as one might like, exhibited on and off reliability and certainly did little to reduce labour requirements.

A modern automated control system, on the other hand, should achieve the following: reduce labour requirements, undertake actions or measurements beyond human capability or acuity and make logical decisions rapidly and consistently. By freeing the human operator from mundane, repetitive and often dangerous tasks, he is now able to devote his time to general supervision, corrections of unpredictable breakdowns, maintenance of fuel handling, combustion, and control equipment, and design improvements.

In making the decision to incorporate an automated control system one must be careful to bear in mind that the system will be less flexible and adaptable than humans, intolerant of design error, dependent on human intervention if incorrectly programmed and incapable of learning from past

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events or of predicting future ones. In forming the decision to use an automated control system one must accept that every component and step must be completely defined, that all the relationships between components and their interactions must be completely understood and included in the design and that every component must be suited to the specific application. The term component in this context by no means applies only to control and sensing elements. If a complete understanding of the interactions and relationships of fuel handling, combustion, and safety and operating controls does not preceed the system design, one is better off leaving the system control to an adaptable, flexible and tolerant human operator.

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CONTROL SYSTEMS FOR WOOD FIRED BOILERS

The purpose of the control system for a wood fired boiler is to satisfy the demand for boiler output by:

1) Controlling the combustion process, and

2) Controlling the fuel flow to the combustor.

A secondary, though no less important purpose is to detect any problems (which are not automatically corrected) in the fuel flow, combustion process or boiler's safe operation and to take appropriate action (either a "warning" or an "alarm" combined with a system shutdown).

CONTROL OF COMBUSTION PROCESS

The general requirements of combustion control are to:

1. Maintain desired temperature or pressure in the boiler.
2. For short periods (less than 30 hours) with very little demand keep the combustion idling on low fire.
3. Increase the firing rate from low fire mode on demand.
4. Provide reasonable response time to boiler demand.

The combustion of solid fuels, especially those containing significant quantities of water, must be recognized as a continuous process once initiated. It cannot be switched on or off instantly. In order to maintain efficient combustion one must recognize the three significant stages of wet fuel combustion.

The first stage is the drying of the fuel which is a heat absorbing process. The second is the release of volatile gases and the third is the consumption of the fixed carbons. The second and third stages will when mixed with oxygen and ignited, produce heat for the boiler.

In order to arrive at optimum performance, the proper fuel-air ratio must be obtained and maintained.

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It is not only necessary to maintain a fire, the firing rate must be controlled. There are basically two methods of controlling the firing rate. The most common is based on high and low firing. As long as the boiler temperature or pressure demand is not satisfied, the system will remain in the high fire mode, normally adjusted for 100% of rated output. When the temperature or pressure demand is satisfied, the system reverts to the low fire or standby mode.

This type of system is normally designed for manual setting of combustion air dampers and the fuel feed rate. This setting is normally done when in the high fire mode, where deviations of efficiency will have the most significant impact. Once set, it requires no further adjustment provided the fuel characteristics do not change significantly. The only adjustment for the low fire mode is in the fuel feed rate.

A combustion system with high and low firing modes is very inexpensive, reliable and fully automatic. Since there are few adjustments (fuel and air supply rates) made at 100% output, it is quite easy to obtain the best possible combustion efficiency the furnace design will allow.

Another method of controlling the firing rate is by means of a fully modulating system. The modulating range is

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normally between 30 and 100% of the rated output. In case the demand drops below 30%, there still must be a low fire mode (i.e. natural draft and minimal fuel feed). Within the modulating range, the firing rate will increase or decrease depending on the degree of departure from the set point of boiler pressure or temperature. With a properly designed system, the pressure can be maintained within two (2) psi. Since the firing rate is now modulating, it is very important that the proper fuel-air ratio be maintained throughout the entire range.

This is accomplished by motor actuators for all air dampers (underfire as well as overfire) and a variation of the fuel infeed rate (the speed of the stoker screw). If the furnace is equipped with a moveable grate system, its speed, also, must be altered to suit the required firing rate.

There is a difficulty with this type of system. It is possible but expensive to design a very flexible system for fine tuning the combustion throughout the entire modulating range in perhaps 5% increments. However, the furnace design may prevent this. Gas flow patterns will change at lower flow rates affecting the mixing of oxygen and volatile gases. In order to reach a compromise, the maximum efficiency is usually achieved in the range of 80% to 100% of output. For

lower capacities, the system will be operating at lower efficiencies.

Clearly, a more complicated system has a greater probability of design error or failure. There are applications, however, where a fully modulating system is required, for example when hot combustion gases are used in a process such as drying.

It should also be pointed out that partially modulating systems are to be avoided.

If, for example, we combine a variable fuel feed rate with fixed combustion air feed rates (i.e. manual dampers) the system will not work well for outputs other than that for which the dampers are set. In case this was 80% of rated output, for firing (or more properly fuel feed) rates higher than 80% the combustion would be starved for oxygen and at lower fuel feed rates excess oxygen would increase stack losses. This in effect allows for increased fuel consumption rates during periods of less than optimum efficiency resulting in poorer overall efficiency than a high/low fire system with lower efficiency occurring only during periods of very low fuel consumption.

Generally, wood boilers should be base loaded to the extent possible. This is dictated by their large first and

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low operating costs. Whenever this is achieved, there is no need for a modulating combustion control system. The system will remain in the high fire mode. Within reason, particularly for heating plants, it is not necessary to have modulating control to follow even a varying boiler pressure or temperature setting.

The specific elements which constitute a normal combustion control system are the typical boiler pressuretrol or aquastat, the stoker drive (either timed-fixed speed or variable speed), the combustion air dampers (either fixed or variable) and the grate drive system (if so equipped).

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CONTROL OF FUEL HANDLING

Biomass fuels present a broad variety of characteristics. This increases the difficulty of achieving an even fuel flow to the boiler. The primary purpose of this system is to feed the furnace with the amount of fuel required for efficient combustion.

Generally a metering bin with some surge capacity is used. A high level sensing device within this bin will be the main controller turning the fuel conveying equipment off. A second low level sensing device can be used to turn the fuel conveying equipment on, but more usually a cumulative timer used in conjunction with the stoker motor is used for this purpose. In very large plants, it may be deemed appropriate to modulate the conveying equipment (rather than start and stop large motors) to meet the actual demand for fuel.

It is likely that fuel plug ups will occur at transition points, that is, where one conveyor empties into another or the type of conveyor changes. For this reason it is essential to halt the flow of fuel to the plug area while maintaining the operation of down stream conveyors. All likely points of plugging should be monitored with suitable sensors or limit switches and the corrective action above carried out as well as a suitable operator warning annunciated. Wherever possible conveying system design should limit the likelihood of plugs and allow for automatic first attempts at correction

by the equipment itself. In the event of imminent loss of combustion due to lack of fuel, an alarm should be annunciated.

Typical elements of the fuel handling control system include reliable plug or overfeed sensors at every transition point, current sensing relays and reversing starters for stoker screws, and metering bin level sensors and stoker revolution counters. Where hydraulic equipment is in use, such as for extraction from the fuel bin, such items as high temperature/low level sensors and pressure actuated reversing valves would be added.

SAFETY CONTROLS

All normal boiler safety devices must be included, such as safety valves, high pressure switches, low water cut offs and auxiliaries. These warrant little discussion, however several additional safety devices are recommended.

Flame failure is usually detected by a temperature sensor between the boiler and induced draft fan. No automatic corrective measure is possible, but an alarm is announced and the entire system is shut down. If this were not to occur, the system would eventually remain in high fire, filling the furnace with fuel.

Fuel feed fault, either due to a conveyor plug or failure to refill the metering bin in a proper amount of time should be announced by alarm.

High furnace temperature should be monitored and if it occurs, the system should be forced into low fire.

Any backfire in the stoker should be detected and extinguished. Since this is most likely to occur during power failures, the detection and extinguishing system must operate without electricity.

Failure of the I.D. fan to operate at full speed will result in a reduction of the ability to vent furnace gases.

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I.D. fan shaft speed should be monitored and any drop should force the system to low fire.

While the I.D. damper will normally be automatically adjusted to maintain draft under all conditions, positive pressure condition could exist with its associated inconveniences. This condition should be detected and the system forced into low fire.

Any of the following conditions should force an emergency system shut down:

1. Motor overload for hydraulic power unit, fuel conveying motors or stoker screw.
2. Flow of water to the backfire extinguishing sytem.
3. High steam pressure or high water temperature in the boiler.
4. Low boiler water level as indicated by the auxiliary LWCO.
5. Low gas temperature in the breeching.
6. Low oil level or high temperature in the hydraulic power unit.

Any of the following conditions should force low fire operation.

1. Motor overload for combustion air fans, ash conveyor screws, fly ash dump valve, or induced draft fan.
2. Failure to refill the metering bin.
3. Low or no I.D. fan shaft speed.

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4. Positive furnace pressure.

5. High furnace temperature.

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PROGRAMMEABLE CONTROLLERS

In the interest of reducing cost, space and maintenance requirements the logic or program of the system is normally stored in a computer or microprocessor rather than using a multitude of interconnected relays. These devices provide a number of advantages over relays such as reliability, ease of programming, and ease of data acquisition. It should be kept in mind that the programmeable controller accomplishes nothing that cannot be accomplished by a properly constructed arrangement of relays, timers and wire.

Units that are commonly used in our field include the Allen-Bradley PLC4, SLC 100 and General Electric Series One.

Like the program element of any control system a microprocessor requires input to create output. The PLC is continously scanning the status of all inputs to determine if they are off or on and responds (according to the programmer's logic) by turning outputs off or on.

Normally, inputs and outputs must be of a digital nature, that is the controller asks a series of yes or no questions of proximity switches, limit switches, temperature/pressure switches, motor status contacts or selector switches/push buttons and responds by issuing do or do not commands to motor

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starters or pilot lights.

The nature of the PLC, however, offers an excellent aid to system troubleshooting. Most devices have status indicator lights for each input and output. By making notes of which lights are off or on during normal operation and noting any discrepancies during a system problem, the fault should be traceable to a specific input. Armed with a copy of the I/O connection drawing supplied with the system, the problem can be quickly pinpointed to a particular switch or sensing device, which is either detecting a problem in the system or requires adjustment or replacement.

While there are certainly many aspects of wood fired boiler control systems that have not been covered, keep the following points in mind when designing or selecting a control system.

1. Start with a well designed fuel handling and combustion system. If these cannot be operated manually as desired, no control system can make them operate properly.

2. Completely understand the interaction of all aspects of the system and reflect this understanding in the control logic so that proper decision making routines are developed.

3. Select sensing and action elements which are suited to their intended task. Devices subjected to severe operating conditions should be appropriately robust. Devices subjected to normal service conditions need not be of nuclear power plant quality.

4. If you are conducting a full scale demonstration or research project, by all means install whatever additional monitoring and recording devices are necessary. If you are operating a normal heating plant, consider spending the money instead on labour saving or maintenance equipment, or spare parts.

5. Don't expect miracles. A control system cannot make decisions it has not been programmed to, it will only make them faster and more consistently than a human operator.

APPENDIX 3

BROOKDALE NURSERIES LTD.

BROOKDALE NURSERIES LTD.

Brookdale Nurseries Ltd., a family ownen wholesale - retail operation, growing cut flowers, potted plants and bedding plants.

Several years ago, due to escalating energy cost, it was decided to utilize our local form of energy for the majority of our heating requirements, rather than burn foreign oil. For the first three years, we hand-fired one boiler with solid wood fuel, mostly hardwood. As this was quite labour intensive, we decided to automate the system using wood chips versus 3 ft hardwood.

In 1982, one boiler was retrofited and automatic woodfiring got underway, using approximately 1200 tons of wood chips annually. We continued to feed solid wood to a second boiler until 1985 when it also was fitted with an automatic feeder. Having learned much from the problems of our first venture, we were able to somewhat streamline the second unit. With some minor changes and adjustments, this unit worked quite well. By January 1987, realizing that the components of the first unit were undersized and too light we undertook a modification. Through on-hands experience, and studying the weak points of this unit we were able to "beef-it-up" so to speak. The mechanical aspect was made much stronger and more streamlined, thus eliminating 60% of the moving parts.

Today, Brookdale operates 2 modified heating plants, Scotch dry back boilers retrofitted with Dutch ovens and also automatic feeders.

We produce 2000-2500 tons of wood chips annually; also some chips are purchased locally.

This production of chips replaces approximately 15,000 gallons of oil. In the greenhouse business, consumption of fuel depends on weather conditions, length of heating season, amount of space heated, etc., thus the variance in our estimates.

APPENDIX 4

SUMMARY OF SEMINAR EVALUATION FORMS

APPENDIX 4

SUMMARY OF SEMINAR EVALUATION FORMS

1. Into which category do you best fit?
   - 5 Professional Engineer
   - 5 Manager
   - 3 Owner
   - 10 Plant Engineer
   - 4 Government Department

2. What parts of the seminar did you find particularly helpful?
   - 11 Boiler Operator Sessions
   - 9 Site Tours
   - 3 New Technology Demonstrations
   - 3 Complete Seminar Presentation
   - 1 None At All
   - 1 No Answer

3. What parts of the seminar would you change to make it more effective?
   - 7 Would not change any part
   - 3 Non-boiler operators allowed to attend operator sessions
   - 2 Too academic
   - 2 More operator discussions
   - 2 More new out-of-province information
   - 1 More A/V material
   - 1 More site visits
   - 1 Smaller tour groups
   - 9 No answer

4. On which specific topics would you like to have additional information?
   - 4 Feed/storage
   - 3 Maintenance
   - 2 Controls
   - 2 Residue
   - 2 Fuel delivery
   - 1 Combustion
   - 1 Supplies
   - 11 No answer

5. Technical level
   - 24 Just right
   - 5 Too general
   - 0 Too specific

6. Has this seminar convinced you to take action to reduce energy consumption and operating costs?
   - 17 Yes
   - 4 No
   - 8 No answer

APPENDIX 5

CONVERSION FACTORS

BIOMASS ENERGY VALUE

APPENDIX 5

BIOMASS ENERGY VALUE

1. Assumptions

i) Boiler Efficiency: Oil - 83%

Hog Fuel - 70%

ii) 1 dry tonne hog fuel: 20.193 Giga Joules (GJ)

*1 green tonne hog fuel @ 41.8% moisture content = 10.672 GJ (see Appendix II)

iii) 1 barrel Bunker "C" Oil: 6.508 GJ

2. Chip Harvester Hog Fuel

1 green tonne - (70% efficiency) 10.672 $\frac{\text{GJ}}{\text{green tonne}}$)

- 7.47 GJ/green tonne available to be converted into steam.

3. Bunker "C" Oil

1 barrel - (83% efficiency) (6.508 GJ/bbl)

- 5.402 GJ/barrel available to be converted into steam.

4. Oil Equivalent of Hog Fuel:

1 green tonne hog fuel - $\frac{7.47 \text{ GJ/green tonne}}{5.402 \text{ GJ/barrel}}$

- 1.38 barrels

5. Value of Hog Fuel

1 green tonne hog fuel - (1.38 $\frac{\text{bbl. oil}}{\text{green tonne}}$)

- $48.40/green tonne

($35.00/bbl. oil)

CONVERSION FACTORS

1. FUNDAMENTAL CONVERSIONS

BRITISH UNITS		SI UNITS	
1 lb. green wood	= 4,170 BTU	1 kg green wood	= 9,700 KJ
1 gal. diesel	= 156,360 BTU	1 L diesel	= 36,288 kJ
1 gal. gasoline	= 144,600 BTU	1 L gasoline	= 33,559 kJ
1 gal. lub. oil	= 163,680 BTU	1 L lub. oil	= 37,987 kJ
1 gal. stove oil	= 151,440 BTU	1 L stove oil	= 35,146 kJ
1 lb. grease	= 18,010 BTU	1 kg grease	= 41,891 kJ
1 gal. propane	= 110,000 BTU	1 L propane	= 25,529 kJ
1 kWh	= 3,414 BTU	1 kWh	= 3,600 kJ
1 cunit	= 2.25 green tons	1 m^3	= 0.72084 green tonnes
1 cord	= .85 cunits		
1 unit residue	= 200 cu. ft.		

2. BRITISH - SI CONVERSIONS

1 m = 3.2808 ft.

1 m^3 = 0.35315 cunits (=0.41547 cords)

1 L = 0.21997 Imp. gallons (=0.26417 U.S. gal.)

1 kJ = 0.94781 BTU

1 tonne = 1.1023 tons

1 km = 0.62137 miles

1 kg = 2.2046 lb.

3. DERIVED CONVERSIONS

1 L d.e./m^3	= 1.6054 gal. d.e./cunit
1 kJ/m^3	= 0.37260 BTU/cunit
1 L d.e./t-km	= 3.1138 gal. d.e./ton-mi
1 kJ/t-km	= 0.7226 BTU/ton-mi
1 kg/m^3v	= 160 tons/unit residue
1 L/(100 km)	= 1/(mpg. x 0.00354)
1 m^3v	= 0.028317 $ft.^3$

NOTE: The symbol v is used here to distinguish cubic metres of volume from cubic metres of solid wood.

Fuel Characteristics

- No 2 fuel oil heating value = 38 340 kJ/liter (165 000 Btu/Imperial gallon)
- No 6 Bunker C oil heating value = 41 830 kJ/liter (180 000 Btu/Imp gal)
- Minto Coal heating value = 26 741 kJ/kg (11 500 Btu/lb)
- Wood Pellets (12% MC) heating value = 17 393 kJ/kg (7 480 Btu/lb)
- Propane heating value = 26 161 kJ/L (112 724 Btu/Imp gal)
- Natural Gas heating value = 37 258 kJ/m^3 (1000 Btu/ft^3)
- Wood residue:

	Heating Value	Bulk Density
25% MC	15 810 kJ/kg (6 800 Btu/lb)	179.4 kg/m^3 (11.2 lb/ft^3)
40% MC	14 124 kJ/kg (6 075 Btu/lb)	201.9 kg/m^3 (12.6 lb/ft^3)
80% MC	10 985 kJ/kg (4 725 Btu/lb)	257.9 kg/m^3 (16.1 lb/ft^3)

CONVERSION FACTORS

IMPERIAL RELATIONSHIPS

1 imperial gallon Bunker "C" oil	-	176,376 BTU
1 barrel oil	-	34.9726 imperial gallons
1 barrel oil	-	6,168,000 BTU
1 dry pound hog fuel	-	8,700 BTU
1 dry ton hog fuel	-	17,400,000 BTU

METRIC CONVERSION FACTORS

1 BTU	-	1,055 Joules (J)
1 barrel oil	-	6.508×10^9 Joules
	-	6.508 Giga Joules (GJ)
1 dry tonne hog fuel	-	20.193×10^9 Joules
	-	20.193 GJ

FOR MOISTURE CONTENT - 41.8%

1 green tonne hog fuel - (1 - 0.418) (20.193 GJ/dry tonne)

- 11.752 GJ

Minus energy required to vapourize the water 1BTU to heat 1lb. of water by 1° F (assume wood at 70° F)

= (212 - 70°) (2200) (0.418)

= 130,583 BTU

Plus Latent heat of vapourization

= (970 BTU/lb) x (2200 x 0.418)

= 892,012 BTU

Total = 130,583 + 892,012

= 1,022,595 BTU (1.08 GJ)

1 Green tonne hog fuel = 11.752 - 1.08

= 10.672 GJ

New Brunswick
Nouveau-Brunswick

Canada